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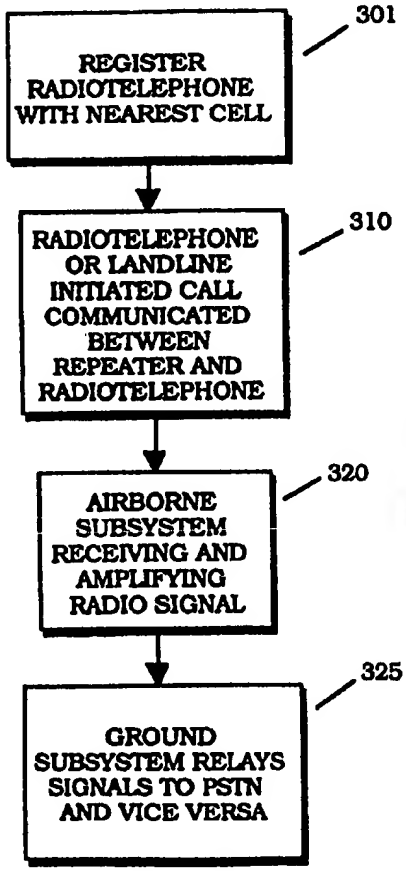
(54) Title: AIRBORNE RADIOTELEPHONE COMMUNICATIONS SYSTEM

(57) Abstract

The airborne radio communications system of the present invention enables an airborne radio to communicate with the ground based cellular radiotelephone system. The present invention also enables the ground based system to keep track of the location of the airborne radiotelephone and page it when a call from the ground based telephone system is received. The ground base station is connected to upward radiating antennas that form airborne cells. As the aircraft with the radio flies through the airborne cells, the airborne relay receives the signals from the base station and relays them to the radio. If the radio is transmitting signals, the relay transmits those signals, through the airborne cells, to the base station. As the aircraft moves from cell to cell, the radio is handed off to the next cell to maintain communications with the ground.



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AIRBORNE RADIOTELEPHONE COMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

I. FIELD OF THE INVENTION

The present invention relates to the field of communications. More particularly, the present invention relates to cellular radiotelephone communications between an airplane and a ground based station.

II. DESCRIPTION OF THE RELATED ART

Present communications technology enables aircraft passengers to make telephone calls to anywhere in the world from any properly equipped airplane. Large airline-type aircraft as well as smaller general aviation-type aircraft can be equipped with the radiotelephone equipment.

A radiotelephone conversation is typically accomplished by first entering the telephone number to be called as well as credit card information to pay for the call. The radiotelephone then connects with one of 70 – 80 radiotelephone base stations, also known as cells, on the ground. The cell to which it connects depends on to which base station the aircraft is closest when the call is initiated. The cells, each connected to the public switched telephone network (PSTN), cover most of the continental United States, thus allowing a telephone call to be initiated from an aircraft almost anywhere.

Aircraft radiotelephones, however, experience a number of problems. First, the aircraft based radiotelephone does not register in the ground based system. The ground based system, therefore, does not know the location of the aircraft radiotelephone. This restricts the aircraft radiotelephone to initiating calls; it cannot receive calls since the ground system does not know where to forward calls.

Another problem is that the aircraft radiotelephone system does not perform hand-offs between cells as is done in ground based cellular radiotelephone systems when the radiotelephone reaches the edge of the cell. This results in the call from the aircraft radiotelephone being dropped when the aircraft reaches the limit of the cell's coverage. There is a resulting need for an airborne radiotelephone system that is compatible with the ground based cellular radiotelephone system. In other words, an airborne radiotelephone system is needed that enables ground initiated

telephone calls to be received by the airborne radiotelephone in addition to the call from the airborne radiotelephone being handed off to the next cell as it reaches the edge of the cell's coverage.

SUMMARY OF THE INVENTION

The system of the present invention encompasses an airborne communications system having a ground based subsystem and an airborne based subsystem. The airborne based subsystem includes a radio for transmitting and receiving radio signals and an airborne radio repeater for relaying the radio signals from the airborne radio to the ground based subsystem. The radio repeater also relays radio signals from the ground based subsystem to the airborne radio. The ground based subsystem includes a base station that is coupled to a public switched telephone network (PSTN) for transmitting PSTN originated signals and receiving relayed radio signals. The base station has at least one upward radiating antenna for transmitting and receiving the radio signals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the airborne radiotelephone communications system of the present invention.

FIG. 2 shows the airborne based subsystem of the present invention.

FIG. 3 shows a flowchart of the process of the present invention.

FIG. 4 shows a block diagram of an alternate embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The airborne radiotelephone communication system of the present invention is illustrated in FIG. 1. This system is comprised of two subsystems: the ground based subsystem (105) and the airborne based subsystem (125).

The ground based subsystem (105), in the preferred embodiment, is the code division multiple access (CDMA) cellular radiotelephone system. An alternate embodiment uses the time division multiple access system. Another alternate embodiment uses the present advanced mobile phone system (AMPS). A typical CDMA radiotelephone system is discussed in

greater detail in U.S. Patent No. 4,901,307 to Gilhousen et al. and assigned to Qualcomm, Inc.

The ground based radiotelephone system is comprised of a base station (120), also known as a cell site, coupled to a mobile switching center (115) that is coupled to the public switched telephone network (PSTN) (110). The base station (120) communicates with the mobile radiotelephones and switches the signals from the radiotelephones to the mobile switching center (115). The base station (120) also provides the proper channels to the radiotelephone, thus enabling communication with the base station. The mobile switching center (115) switches the signals from the base station (120) to the PSTN (110) and vice versa.

Each base station (120) is coupled to an antenna (150) that receives and radiates the CDMA radiotelephone signals. In the preferred embodiment, the antenna (150) is identical to typical cell site antennas that are well known to one skilled in the art. An alternate embodiment uses an antenna that radiates upward. This upward radiation forms a cell that is elevated above the ground allowing the airborne radiotelephone to travel through the elevated cells in the same manner that a mobile radiotelephone on the ground travels through terrestrial cells. An antenna that forms this type of elevated cell is a typical directional antenna that is well known in the art.

A block diagram of the airborne based subsystem of the present invention is illustrated in FIG. 2. This subsystem uses a CDMA-type radiotelephone (205) to communicate with a radiotelephone signal repeater (210), having an antenna, that is located in the aircraft. In the preferred embodiment, the repeater (210) also has an amplifier to increase the signal's gain that is being communicated to the repeater.

The repeater (210) receives the signals from the individual radiotelephones (205) within the aircraft and relays them to an antenna (215) mounted on the outside of the aircraft. The outside antenna (215) relays the signals to the base station on the ground. This subsystem may have a single radiotelephone, as in a small aircraft, or multiple radiotelephones, as in an airline size aircraft.

The airborne subsystem also operates in the reverse direction. Telephone calls from the PSTN to the base station on the ground are transmitted to the outside antenna (215) that relays them to the repeater (210) mounted in the aircraft. The repeater's antenna communicates the signal to the proper radiotelephone (205) in the aircraft. The radiotelephones (205) determine which signal is to be decoded by the

process described in *Gilhousen et al.* and in the Telecommunications Industries Association/Electronic Industries Association Interim Standard 95 (TIA/EIA/IS-95).

In an alternate embodiment, the radiotelephone signal repeater is replaced by an airborne base station that has the ability to register the radiotelephones on the aircraft. The airborne base station then registers the radiotelephone with the ground based subsystem. This base station has the same functionality of its ground-based counterpart but on a much smaller scale since it does not have to handle the thousands of radiotelephones of the ground-based station.

The airborne communications system of the present invention operates in a similar way to the ground based CDMA radiotelephone system discussed in *Gilhousen et al.* A flowchart of this operation is illustrated in FIG. 3.

The process begins by the airborne repeater registering the radiotelephone with the nearest cell site (301). This is accomplished in the same manner as a terrestrial radiotelephone registers with the ground based radiotelephone system; the repeater searches for the strongest pilot signal and registers with that cell. This registration process involves the radiotelephone's telephone number and electronic serial number being transmitted to the base station. The registration process is described in greater detail in U.S. Patent No. 5,289,527 to Tiedemann and assigned to Qualcomm, Inc.

The radiotelephone or ground-based land-line telephone system can now initiate a call (310). The call from the radiotelephone is received by the airborne repeater and amplified (320) before being transmitted to the ground base station. The ground base station then transmits the call to the mobile switching center that routes the call to the PSTN where it is then connected to the called telephone number (325).

The signals from the PSTN to the airborne radiotelephone are routed in the reverse of the radiotelephone initiated call. The mobile switching center switches the call to the base station to which the radiotelephone is registered. The base station then transmits the signal (325) to the airborne external antenna that relays it to the aircraft repeater (320). The repeater amplifies it and transmits the amplifier signal to the radiotelephone in the aircraft.

The present invention also enables a ground telephone or radiotelephone to contact an airborne radiotelephone. Since the repeater has registered the airborne radiotelephone with the proper ground base

station, the mobile switching center knows to which base station the call is to be routed. Once the call is routed to the proper base station it is transmitted to the airborne repeater which then amplifies the call and transmits it to the radiotelephones on the aircraft. As discussed above, the radiotelephones then determine which signal is to be decoded.

Another benefit of the present invention is the hand-off capability. Once the aircraft reaches the fringe of the present cell site, the radiotelephone begins the hand-off process described in *Tiedemann*. The signals from the ground base stations are received by the external antenna of the airborne subsystem and repeated to the radiotelephones. This enables the radiotelephones to search for the strongest pilot signal of the next cell and register with that base station. The determining factor on when the quality of the pilot signal has been reduced to the point that a hand-off is required is when the pilot signal drops a predetermined amount. This amount may be different for every system and is set to optimize the system performance.

In the alternate embodiment, the airborne repeater is replaced by a base station-type unit that registers the radiotelephone aboard the aircraft. A block diagram of the airborne base station is illustrated in FIG. 4. Once the radiotelephone is registered with the aircraft base station, the aircraft base station then searches for the strongest pilot signal from a ground base station and registers with that base station.

Referring to FIG. 4, the airborne base station is comprised of a number of base station transceivers (410) that are the link between the radiotelephone and the base station. The CDMA interconnect subsystem (415) routes the signals between the transceivers (410) and the rest of the base station. The call control processor (420) controls signaling with the radiotelephones, controls all call processing, and allocates the base station resources. The time and frequency unit (430) provides the timing and frequency signals for the base station. The base station manager (435) performs initialization, configuration, and performance management of the base station. And finally, the selector bank subsystems (440) processes and formats the data between the ground base stations and the radiotelephone. The selector bank subsystems (440) are connected to the aircraft's external antenna (315) to receive and radiate the radiotelephone signals.

Other embodiments using the airborne base station may have different components and different features. A base station that simply

registers the radiotelephone and relays this registration to the ground base station is also within the scope of the present invention.

CLAIMS

1. An airborne communications system having a ground based subsystem and an airborne based subsystem, the communications system comprising:

an airborne radio, in the airborne based subsystem, for transmitting and receiving radio signals;

an airborne radio repeater for relaying radio signals from the airborne radio to the ground based subsystem and for relaying radio signals from the ground based subsystem to the airborne radio; and

a ground based subsystem base station, coupled to a public switched telephone network (PSTN) for transmitting PSTN originated signals and receiving relayed radio signals, the base station having at least one upward radiating antenna for transmitting and receiving the radio signals.

2. The communications system of claim 1 wherein the repeater has the capability of registering the airborne radio with the base station.

3. An airborne communications system having a ground based code division multiple access (CDMA) radiotelephone subsystem and an airborne based subsystem, the communications system comprising:

an airborne radiotelephone, in the airborne based subsystem, for transmitting and receiving CDMA signals;

an airborne base station for registering the radiotelephone with the ground based CDMA radiotelephone subsystem and relaying CDMA radio signals from the airborne radiotelephone to the ground based subsystem and for relaying CDMA radio signals from the ground based subsystem to the airborne radio; and

a CDMA base station in the ground based CDMA subsystem, coupled to a public switched telephone network (PSTN), for transmitting PSTN originated signals and receiving relayed CDMA radio signals, the base station having a plurality of upward radiating antennas for transmitting and receiving the radio signals.

4. The airborne communications system of claim 3 wherein the plurality of upward radiating antennas substantially precluding radiation of the CDMA radio signals at ground level.

5. An airborne radiotelephone system, comprising:

an airborne radiotelephone having a capability for transmitting and receiving code division multiple access (CDMA) radiotelephone signals;

a plurality of base stations, coupled to a public switched telephone network (PSTN), for coupling received CDMA radiotelephone signals to the PSTN and for converting PSTN signals to CDMA radiotelephone signals for transmission to the airborne radiotelephone; and

a plurality of upward radiating antennas, each antenna coupled to a first base station of the plurality of base stations, for receiving and radiating the CDMA radiotelephone signals, the plurality of upward radiating antennas substantially precluding radiation of the CDMA radiotelephone signals at ground level.

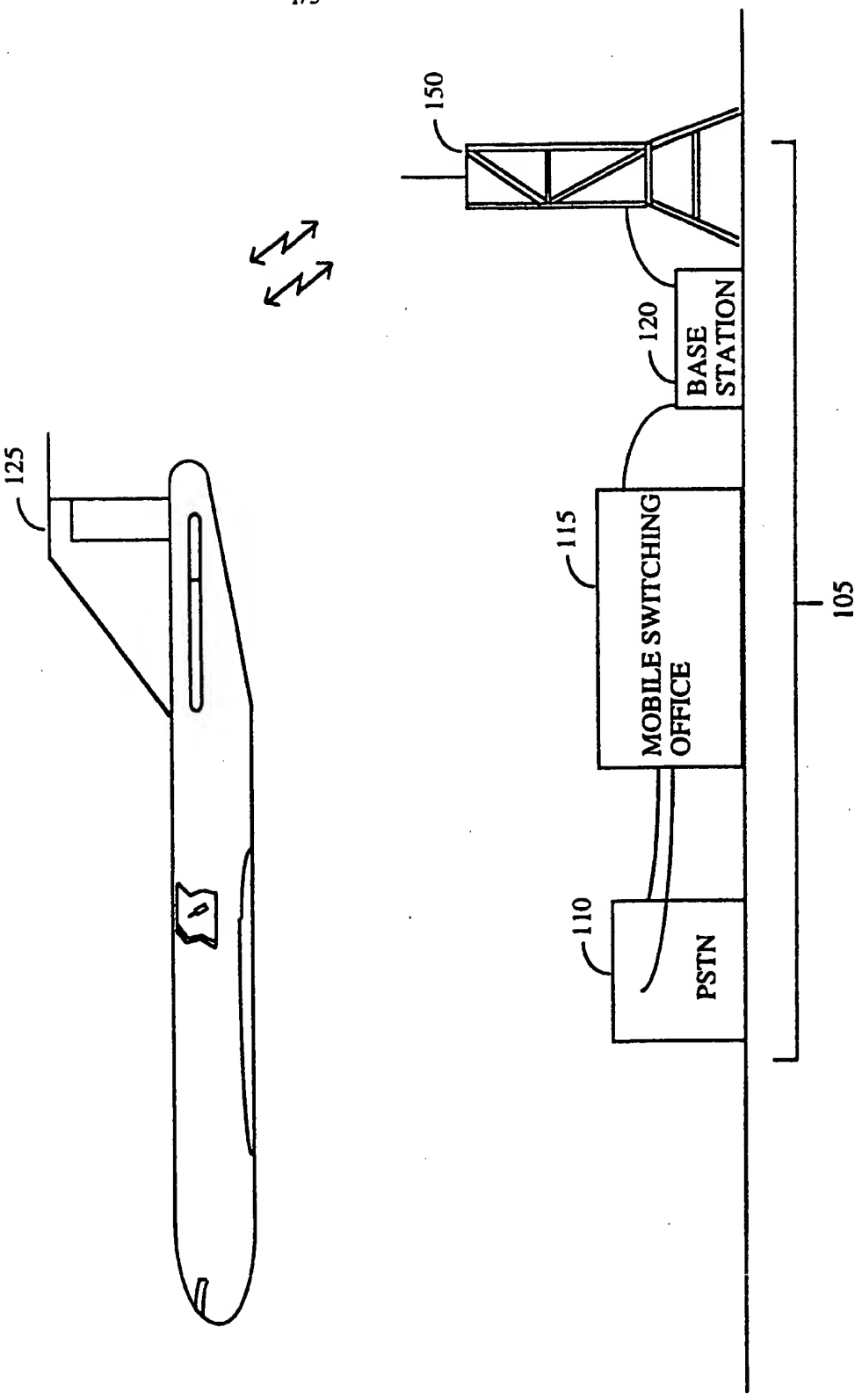
150
120
BASE STATION
125
115
MOBILE SWITCHING OFFICE
105
110
PSTN

FIG. 1

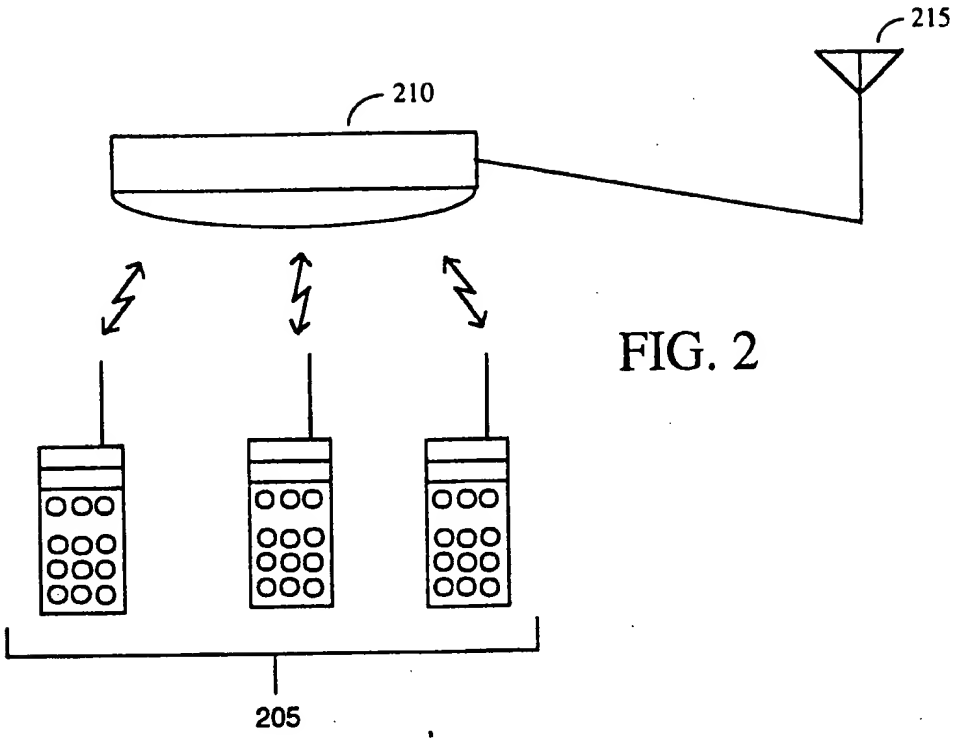
215
210
205

FIG. 2

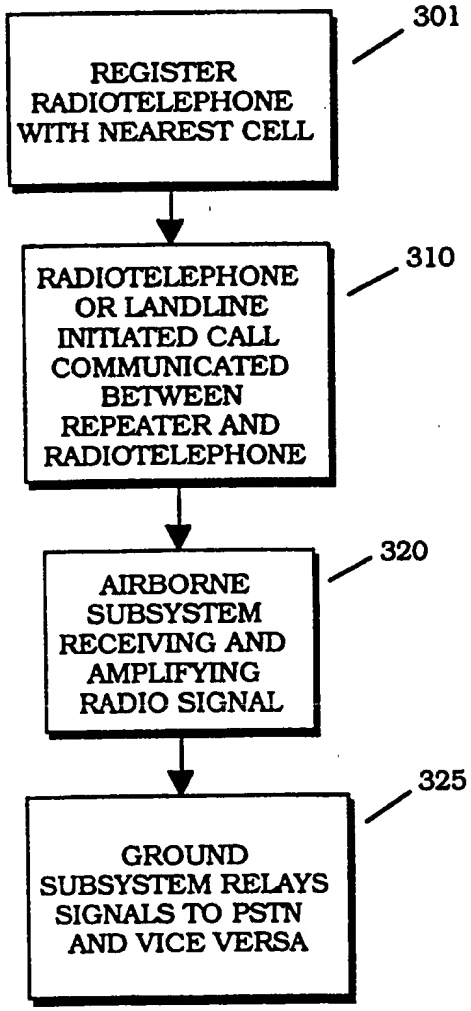
301
REGISTER RADIOTELEPHONE WITH NEAREST CELL
310
RADIOTELEPHONE OR LANDLINE INITIATED CALL COMMUNICATED BETWEEN REPEATER AND RADIOTELEPHONE
320
AIRBORNE SUBSYSTEM RECEIVING AND AMPLIFYING RADIO SIGNAL
325
GROUND SUBSYSTEM RELAYS SIGNALS TO PSTN AND VICE VERSA

FIG. 3

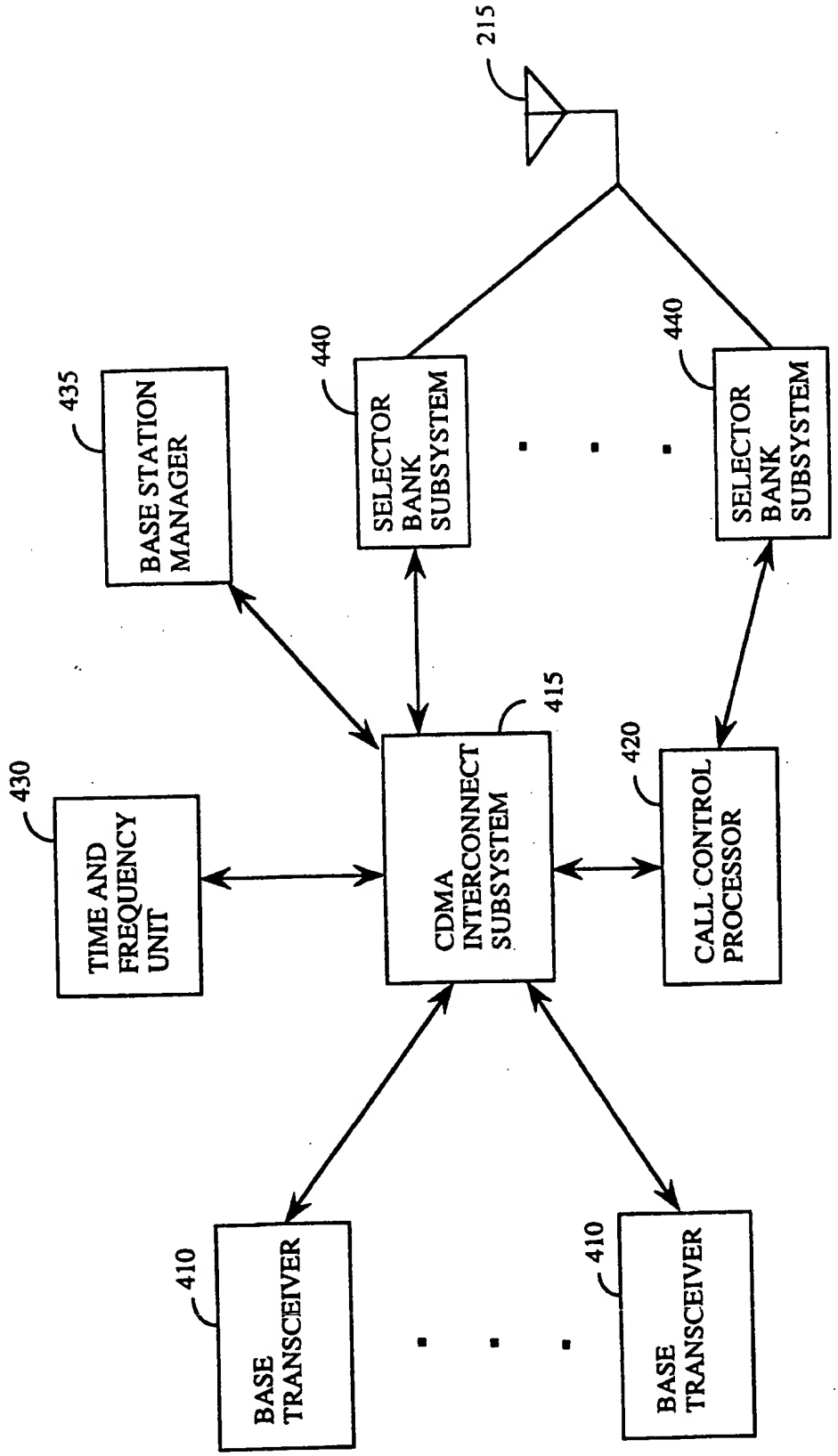
215
440
SELECTOR BANK SUBSYSTEM
440
SELECTOR BANK SUBSYSTEM
435
BASE STATION MANAGER
415
CDMA INTERCONNECT SUBSYSTEM
420
CALL CONTROL PROCESSOR
430
TIME AND FREQUENCY UNIT
410
BASE TRANSCEIVER
410
BASE TRANSCEIVER

FIG. 4

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/185

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US,A,5 123 112 (CHOATE) 16 June 1992 see column 3, line 27 - column 4, line 48; figure 1 ---	1,2 3-5
Y	IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, COMMUNICATIONS-SOUND TO LIGHT, vol.1, June 1987, SEATTLE,WASHINGTON,US pages 513 - 519 R.ROGARD ET AL. 'PRODAT Aeronautical Communication System: Overall Architecture and Preliminary Test Results' see page 516, right column, line 29 - page 517, right column, line 23 --- -/--	3-5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 1995	23. 10. 95

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FIFTH NORDIC SEMINAR ON DIGITAL MOBILE RADIO COMMUNICATIONS, December 1992, HELSINKI,FINLANDE pages 123 - 130, XP457846 G.D'ARIA ET AL. 'Terrestrial Flight Telephone System: Integration Issues for a Pan-European Network' see page 125, left column, line 4 - page 126, left column, line 10	1-5
A	MRC MOBILE RADIO CONFERENCE, November 1991, NICE,FR; pages 221 - 228, XP444199 E.BERRUTO ET AL. 'Terrestrial Flight Telephone System for Aeronautical Public Corresponce: Overview and Handover Performance.' see page 223, right column, line 11 - line 21	1-5
A	WO,A,94 05129 (ERICSSON) 3 March 1994 see abstract	2

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WO-A-9405129	03-03-94	SE-C-	500197	02-05-94
		AU-B-	4594693	15-03-94
		BR-A-	9305610	04-04-95
		CN-A-	1083990	16-03-94
		EP-A-	0609412	10-08-94
		FI-A-	941774	15-04-94
		JP-T-	7500471	12-01-95
		SE-A-	9202373	19-02-94